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Assessment of Spatial Variation of Water Quality of Tunggak River Adjacent to Gebeng Industrial Estate, Malaysia

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ABSTRACT

Anthropogenic impact on the Tunggak River is as a result of rapid industrialization in the study area. The study was conducted with the objective to explore the spatial variation of the water quality of the river due to anthropogenic activities. Water samples were collected monthly from selected sites and analyzed applying APHA & HACH standard methods. Trace elements were determined using Inductively Coupled Plasma Mass Spectrophotometer (ICP-MS). SPSS statistical software was used for data analysis. The study revealed that point sources especially industrial wastes contributing the major pollutants. Less amount of dissolved oxygen (DO) and higher concentration of chemical oxygen demand (COD) & ammoniacal nitrogen and trace elements made the water unusable. Based on Department of Environment-Water Quality Index (DOE-WQI) Malaysia, maximum stations except lower and uppermost were categorized as class IV (highly polluted). Pollution was higher in the middle stations due to addition of most of the industrial effluents to those sites.

INTRODUCTION

Water is the most delicate part of the environment which is essential for human and industrial development. Due to increasing population and rapid growth of industrialization the demand of fresh water rises tremendously in the last few decades [1]. The rate of fresh water deterioration by anthropogenic activities is coupled with the ever- growing demands of water resources [2]. Malaysia is subsidized with bounty of natural water resources which is contributing significantly to the socio- economic development of the country [3]. But the situation is changing day by day with population growth, urbanization and industrialization. According to the Environmental Quality Report 2009, 46% river water of Malaysia is polluted which is higher than previous couple of years [4]. The Tunggak is one of the important rivers in Pahang which is adjacent to Gebeng the main industrial area in Kuantan, Pahang, Malaysia. The town Gebeng is located near Kuantan Port; where industrial development is growing rapidly. These industrial activities are generating effluents which contain high concentrations of conventional and non-conventional pollutants that deteriorating the water quality of the river. In the study area, non-point source associated with runoff from construction sites of newly developing industrial areas and the point source contributing the maximum pollutants especially industrial wastes. Industries like, petrochemical, medicinal, wooden and mining are discharging their effluents in the river through various drain/channels. As a result the water of the river contains high amount of ammoniacal nitrogen (NH3-N), less DO and many other components that deteriorate the water quality. The industrial waste water of the study area contain nickel (Ni), mercury (Hg), cadmium (Cd), zinc (Zn), chromium (Cr), lead (Pb) and copper (Cu) [5]. So, the river water quality becomes more polluted. Therefore, the study was done with a view to identify the behavior of the water quality parameters and to disclose the spatial variation of the pollution status of the surface water.

MATERIALS AND METHODS

A. Study Area and Selection of Station

The Tunggak River is situated in between $3^{0}56'06''$ to $3^{0}59'44''$ N and $103^{0}22'42''$ to $103^{0}24'47''$ E adjacent to the Gebeng industrial town holding several types of industries (Fig. 1). Station selection was done considering the land use-pattern, point-sources of pollution, vegetation and river network. Starting from lower stream 10 stations was selected for sampling.

B. Sampling, Data Collection and Analysis

Water samples were collected monthly from pre-selected 10 stations. Three (3) samples were collected from identical 3 positions in every station for replication. Data regarding the position of the station was collected using GPS. BOD samples were carried using separate BOD bottle. APHA & HACH standard procedure was followed during sampling and samples preservation [6-7]. Using YSI in-situ data of pH, Temperature, DO, Turbidity, Salinity, Electrical conductivity (EC), and total dissolved solids (TDS) were also collected during the sampling. For chemical parameters HACH spectrophotometer was used. BOD was calculated with the initial reading collected just after sampling and the final reading after 5 days incubating at 20^{0}C temperature. TSS analyzed by using gravimetric method and heavy metals were determined by ICP-MS. All parameters were analyzed within 7 days of sample collection.

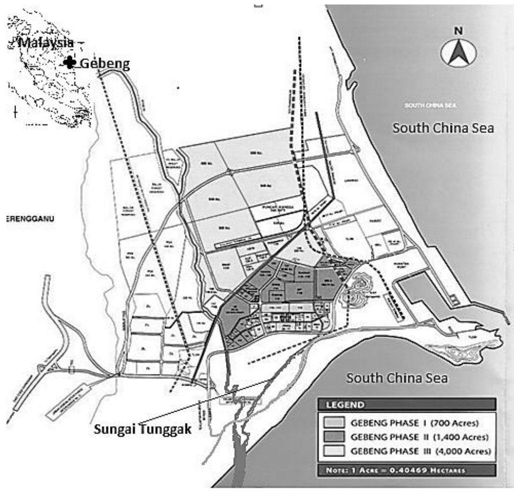

Fig. 1. Map of the study area indicating Tunggak River

C. Data Analysis

The main aim of environmental research is to identify for underlying factors which are not observable directly in database, for this factor analysis technique is suitable [8]. For the factor analysis SPSS statistical software was used to analyze the data. For this study data were analyzed for mean, standard deviation (SD), range, correlation and Analysis of Variance (ANOVA).

RESULTS AND DISCUSSION

A. In-situ Parameters

River water temperature in Malaysia usually ranges from 24^{0}C to 31.3^{0}C [9] and Malaysian normal water temperature is $27\text{-}31^{0}$C [10]. Water temperature of the Tunggak river varied from 26.16°C to 35.24°C among the stations. In most of the stations temperature was within the normal limit of Malaysian standard but the temperature of station 6 to 8 were beyond the standard limit [11] (Table 2). Regarding pH values, it was varied from station to station. The highest pH value 9.12 was recorded in station 6 followed by station 5 and station 7. These three stations received most of the effluents of the industrial estate consist of polymer, chemical, metal, gas & power industries. On the contrary, the lowest value 4.16 was recorded in station 8 followed by station 9 and 10. It was might be because of the industrial effluents at the area of station 8 and 10 contained acidic substances and due to submerge condition at station 9 pH was also low (Table 2). Only the value of pH in station 1 was within the permissible range [11]; perhaps it was due to the tidal interference from South China Sea (Table 1).

Table 1. Physico-chemical parameters of different sampling sites and classification based on INWQS of Malaysia

Parameters	Station no. (total station)	Value/ amount	Water Class
pH	1 (1)	6.0 – 9.0	Class II
	2 – 7 (6)	6.5 - 8.5	Class I
	8 – 10 (3)	5.0 – 9.0	Class III
DO (mg/L)	1,5,7,8 (4)	3.12– 3.38	Class III
	2-4,6 & 9-10 (6)	1.58 – 2.71	Class IV
EC (µS/cm)	1 – 2 (2)	10880-18013	Class IV
	3 – 7 (5)	1068 – 1585	Class II
	8 – 10 (3)	24 – 750	Class I
Salinity (%)	1 – 2 (2)	5.685 – 9.38	Class IV
	3 – 6 (4)	0.52 – 0.715	Class II
	7 – 10 (4)	0.01 – 0.34	Class I
Turbidity (NTU)	1 – 8 & 10 (9)	6.59 – 23.44	Class II
	9	3.87	Class I
TDS (mg/L)	1 – 2 (2)	6250-16137	Class IV
	3 – 6 (4)	613-767	Class II
	7 – 10 (4)	8.15 – 365	Class I

EC readings of the stations were mostly within the normal limit except the 1, 2 & 3 (Table 2). This was because of entering the saline water in these stations during tide from the South China Sea. Concentration of DO recorded very low in all of the stations varies from 1.1 mg/L at station 2 to 4.4 mg/L at station 1 (Table 2). According to INWQS, Malaysia the stations were categorized as class III and IV based on DO concentration (Table 1).

TDS concentration was higher in the lower stream stations compare to the uppermost. Station 1 and 2 contained the highest amount of TDS due to tidal disturbance, forested area and there were some agricultural activities adjacent to the station 2. Meanwhile, TDS of station 7-10 were in permissible limits 500 mg/L [11] (Table 2). Turbidity level varies from 2.1 NTU at station 9 to 34.5 NTU at station 5 (Table 2); only station 9 was in normal level whether rest of all contained higher value of turbidity according to the INWQS, Malaysia.

B. Ex-situ Parameters

Collecting samples from sampling sites were analysed in laboratory for determining the amount of Sulphate (SO_4), NH_3-N, Nitrate-nitrogen (NO_3-N), Phosphate-phosphorus ($PO_4$3-), BOD, COD and TSS. Results showed that the amount of sulphate was highest in station 1 followed by 2 and 7 (Fig. 2).

It was due to station 1 & 2 are located near the sea and station 7 is adjacent with some industries which discharge sulphur reach effluents into the river. The amount of NH_3-N varies from 0.25 mg/L at station 9 to 3.47 mg/L at 3 (Fig. 3). The values were beyond the permissible limit of INWQS of Malaysia [11]. NO_3-N level was within the safe level (<0.4) [9] except station 5-7 (Fig. 3); these three stations received most of the effluents from the industries including polymer, chemical, metal, gas & power and wooden industries in Gebeng. From the analysis $PO_4$3- recorded highest 6.3 mg/L at station 10 (Fig. 3) while the other stations contain relatively low PO43-. Meanwhile $PO_4$3- amount was in permissible level at station 7-9 [11].

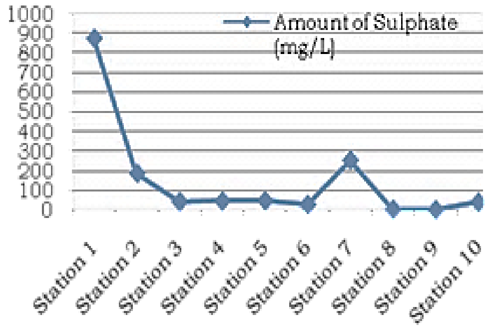

Fig. 2. Variation among the station in case of Sulphate

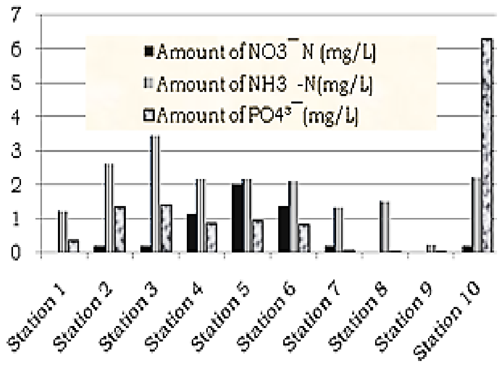

Fig. 3. Status of chemical parameters nitrate-nitrogen, ammonia- nitrogen and phosphorus among the stations.

Biochemical parameters BOD and COD were analyzed and the result revealed that BOD was the highest 32.88 mg/L at station 7 and the lowest was 4.23 mg/L at 9 (Fig. 4). The BOD values at all stations were beyond the permissible limit [11] and it was due to the discharge of industrial wastes in the river flow. In the same way COD value recorded higher at station 7 and lesser at station 9 (Fig. 4). However, COD level recorded safe at station 9 & 10 [11]. Due to the addition of industrial effluents with the river water the quality of water deteriorated and based on the types of industry pollution level of the river differ from station to station.

Heavy metals were determined by ICP-MS and demonstrated in Fig. 5. Result showed that water of the river bearing especially the middle stations containing Co, Cd, Cu, Pb and Cr beyond the permissible level [11]. Adjacent to the river the major industries are chemical, polymer, metal, petrochemical and gas & energy; those effluents bear the toxic heavy metal as a result polluting the surface water of the river.

Table 2. Range, mean and SD for in- situ parameters for 10 sampling stations with geographical coordinate

Station No.	Location GPS)		Temperature (°C)	pH	Conductivity (µS/cm)	DO (mg/L)	TDS (mg/L)	Turbidity (NTU)
1	03°56'35.04"N and 103°22'32.1"E	Range	27.05-30.17	5.66-7.02	14200-27080	2.62-4.40	9040-24300	7.69-22.50
		Mean	28.78	6.23	18013	3.30	16137	16.66
		SD	1.07	0.52	4946	0.61	7691	6.41
2	03°57'19.44"N and 103°22'59.94"E	Range	28.04-29.2	6.97-7.71	7700-13660	1.10-2.17	5160-7270	10.05-24.70
		Mean	28.55	7.28	10880	1.58	6250	17.72
		SD	0.59	0.34	2836	0.41	1088	5.81
3	03°57'39.6"N and 103°23'14.64"E	Range	29.01-29.81	7.32-8.40	1244-1800	1.33-1.80	650-869	9.78-20.70
		Mean	29.34	7.69	1395	1.69	767	13.70
		SD	0.38	0.38	207	0.36	112	3.90
4	03°57'54.18"N and 103°23'22.86"E	Range	30.92-32.57	7.51-8.51	1119-1320	1.62-4.12	527-821	10.05-17.27
		Mean	31.74	7.95	1212	2.71	613	14.14
		SD	0.75	0.35	95	0.96	108	3.42
5	03°58'12.54"N and 103°23'23.28"E	Range	30.92-33.1	6.96-8.95	1380-1630	1.93-3.91	642-748	11.26-34.50
		Mean	31.98	7.96	1505	3.12	700	23.44
		SD	1.07	0.99	107	0.91	50	12.03
6	03°58'33.6"N and 103°23'14.28"E	Range	31.63-34.14	7.25-9.12	1423-1740	1.56-3.16	649-778	11.73-28.80
		Mean	32.88	8.01	1585	2.32	715	20.98
		SD	1.35	0.76	164	0.79	68	8.01
7	03°59'13.44"N and 103°23'16.92"E	Range	33.2-35.24	6.77-8.60	923-1210	2.85-3.93	203-529	6.69-12.35
		Mean	33.78	7.65	1068	3.28	365	9.82
		SD	0.88	0.62	149	0.51	171	2.30
8	03°59'16.44"N and 103°23'17.46"E	Range	32.5-34.1	4.66-5.42	51-58	2.78-4.25	19.6-24.8	4.83-10.06
		Mean	33.27	4.96	55	3.38	21.78	6.59
		SD	0.56	0.29	3.31	0.59	2.25	1.81
9	03°59'27.42"N and 103°24'12.18"E	Range	26.16-27.4	4.23-6.70	20-27	1.93-3.05	7.7-8.7	2.10-6.02
		Mean	26.78	5.13	24	2.34	8.15	3.87
		SD	0.61	1.04	3.39	0.38	0.47	1.56
10	03°59'37.62"N and 103°24'45.3"E	Range	31.12-31.75	5.14-6.40	713-787	2.36-3.01	333-379	7.7-12.24
		Mean	31.45	5.86	750	2.66	354	10.11
		SD	0.29	0.44	36.01	0.22	22.12	2.09

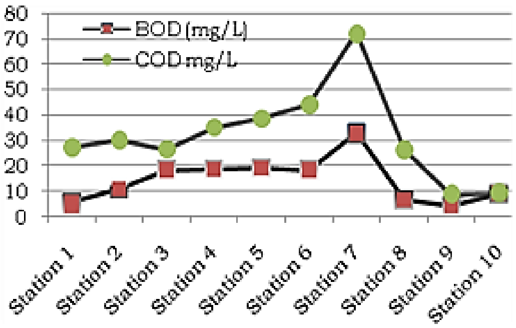

Fig. 4. Status of organic parameters COD and BOD among the stations

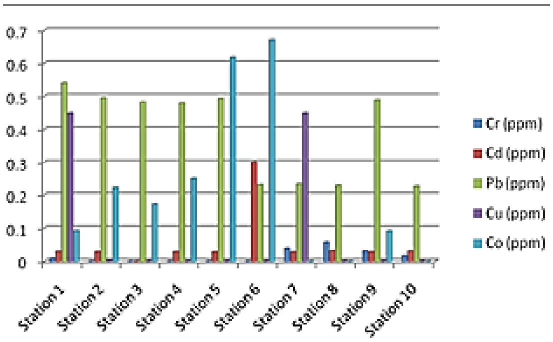

Fig. 5. Status of trace element Concentration among the Stations

C. Water Quality Index

DOE-WQI was calculated to classify the water quality of Tunggak river. The computed values categorized the river water of Tunggak as Class IV (highly polluted) except the lower stream station 1 and upper stream stations 9 & 10. Regarding those three stations, they were categorized as polluted and slightly polluted respectively. That was perhaps at station 1 there was tidal interference and forested areas; and at station 9 & 10 there was less industrial activities generating comparatively lesser effluents. However, according to the Interim National Water Quality Standards of Malaysia, water of the river was found to be unusable without irrigation [11].

CONCLUSION

This study revealed that the pollution level was comparatively higher in the middle stream stations because of maximum wastes discharged to those stations from the industries. On the other hand due to tidal interference at lower stream and less industrial activities at the upper stream caused less pollution in lower and upper stream stations. Considering the analytical results and data analysis it is clear that the major source of pollutant was the industrial activities. To reduce the water pollution level close monitoring of industrial activities should be ensured and emphasis should also be given on recycling of industrial wastes of their own before discharging to the river flow.

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